U.S. Coast Guard Research and Development Center
1082 Shennecossett Road, Groton, CT 06340-6096

Report No. CG-D-10-01

Performance Analysis of Tower Watch Camera Systems

FINAL REPORT
May 2001

Prepared for:

U.S. Department of Transportation
United States Coast Guard
Operations (G-O)
Washington, DC 20593-0001

Report Documentation Page

Report Date 01MAY2001	**Report Type** Final	**Dates Covered (from... to)** -

Title and Subtitle Performance Analysis of Tower Watch Camera Systems	**Contract Number**
	Grant Number
	Program Element Number
Author(s) Hansen, Richard	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, CT 06340-6096	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) U.S. Department of Transportation United States Coast Guard Operations (G-O) Washington, DC 20593-0001	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited	
Supplementary Notes The R&DC technical point of contact is Rich Hansen at (860)441-2866 or rhansen@rdc.uscg.mil., The original document contains color images.	

Abstract
A technology demonstration effort was undertaken to determine if a remote imaging system could be used to reduce workload at a U.S. Coast Guard Small Boat (Surf) Station. The remote imaging system consisted of a black and white Closed Circuit Television (CCTV) system with integrated image intensification and long-range thermal (infrared) imaging. The goal was to determine the extent to which remote monitoring of rough inlet bar conditions and vessel traffic could reduce the need to staff a watch tower. The demonstration project was conducted at U.S. Coast Guard Station Cape Disappointment in Ilwaco, WA. The remote imaging system was controllable both locally at the watch tower site and remotely from the Stations Communications Center. The cameras were mounted on a remotely controllable pan/tilt unit to allow the observer to determine the area of interest. The full motion video signal and all control signals were transmitted back and forth from the watch tower and the Communications Center via fiber-optic cabling. Comparisons were made of the fidelity of the remote imaging systems capabilities to that of traditional monitoring techniques. An operational assessment was made on the impact the remote imaging system had on the operations of the Station. The evaluations identified that the remote imaging system with the long-range infrared camera improved monitoring during adverse weather conditions and darkness. The remote imaging system provided more accurate and timely information to the Stations Duty Officer, thus allowing additional decision-making time regarding resource assignments. Recommendations on remote imaging system requirements and cost estimates are provided to aid in implementation decision making for the Office of Boat Forces (G-OCS).

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU
Number of Pages 17	

N O T I C E

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

This report does not constitute a standard, specification, or regulation.

Marc B. Mandler, Ph.D.
Technical Director
United States Coast Guard
Research & Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

Technical Report Documentation Page

1. Report No. CG-D-10-01	**2. Government Accession Number**	**3. Recipient's Catalog No.**
4. Title and Subtitle Performance Analysis of Tower Watch Camera Systems		**5. Report Date** May 2001
		6. Performing Organization Code Project No. 9999.7
7. Author(s) Richard Hansen		**8. Performing Organization Report No.** R&DC 515
9. Performing Organization Name and Address U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, CT 06340-6096		**10. Work Unit No. (TRAIS)**
		11. Contract or Grant No.
12. Sponsoring Organization Name and Address U.S. Department of Transportation United States Coast Guard Operations (G-O) Washington, DC 20593-0001		**13. Type of Report & Period Covered** Final
		14. Sponsoring Agency Code Commandant (G-OCS) U.S. Coast Guard Headquarters Washington, DC 20593-0001

15. Supplementary Notes

The R&DC technical point of contact is Rich Hansen at (860)441-2866 or rhansen@rdc.uscg.mil.

16. Abstract (MAXIMUM 200 WORDS)

A technology demonstration effort was undertaken to determine if a remote imaging system could be used to reduce workload at a U.S. Coast Guard Small Boat (Surf) Station. The remote imaging system consisted of a black and white Closed Circuit Television (CCTV) system with integrated image intensification and long-range thermal (infrared) imaging. The goal was to determine the extent to which remote monitoring of rough inlet bar conditions and vessel traffic could reduce the need to staff a watch tower.

The demonstration project was conducted at U.S. Coast Guard Station Cape Disappointment in Ilwaco, WA. The remote imaging system was controllable both locally at the watch tower site and remotely from the Station's Communications Center. The cameras were mounted on a remotely controllable pan/tilt unit to allow the observer to determine the area of interest. The full motion video signal and all control signals were transmitted back and forth from the watch tower and the Communications Center via fiber-optic cabling.

Comparisons were made of the fidelity of the remote imaging system's capabilities to that of traditional monitoring techniques. An operational assessment was made on the impact the remote imaging system had on the operations of the Station. The evaluations identified that the remote imaging system with the long-range infrared camera improved monitoring during adverse weather conditions and darkness. The remote imaging system provided more accurate and timely information to the Station's Duty Officer, thus allowing additional decision-making time regarding resource assignments.

Recommendations on remote imaging system requirements and cost estimates are provided to aid in implementation decision making for the Office of Boat Forces (G-OCS).

17. Key Words tower watch, camera system, inlet monitoring, remote imaging, infrared, night vision, image intensification, remotely controlled	**18. Distribution Statement** This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161

19. Security Class (This Report)	**20. Security Class (This Page)**	**21. No of Pages**	**22. Price**
UNCLASSIFIED	UNCLASSIFIED	16	

Form DOT F 1700.7 (8/72) Reproduction of form and completed page is authorized.

EXECUTIVE SUMMARY

The United States Coast Guard (USCG) Small Boat (Surf) Stations are required to monitor the environmental conditions, and vessel traffic, set restrictions when required, and conduct operations over inlet bars within their Area of Responsibility (AOR). The environmental monitoring, although a collateral/secondary duty, is critical to operational success and consists of monitoring weather and the conditions of the inlet (waves, tide, visibility, and other potential restrictive conditions to the safe passage of vessels). This monitoring is currently done by visual observation from an appropriate location on shore or by getting underway in one of the station's small boats. Several Surf Stations have a watch tower located at a convenient location to observe the inlet. These towers are usually located within a mile of the Station. This requires Station personnel to travel to the tower to make observations. Monitoring occurs at a minimum of twice a day (first and last light), as often as every four hours, and more continuously during adverse conditions or times of high vessel activity. The visual observations are limited primarily to daylight hours.

The conditions of the inlet can change in a short period of time due to weather and/or tides. Weather and tides can induce extremely hazardous, steep or breaking wave conditions at the inlets. The observations of these conditions are used to make critical resource decisions for operational assignments or to restrict vessel traffic over the bar. The demands of the conditions monitoring are a continuous drain on Station workload.

The USCG Research & Development Center undertook this project to determine if there are technology-based solutions to the problem. This work was performed in partnership with the Command and Control Engineering Center (C2CEN) for the Office of Boat Forces (G-OCS) of U.S. Coast Guard Headquarters. This project is being performed to support the efforts of Project Kimball.

After a review of numerous Surf Stations and available technology, a remote imaging solution for inlet bar observation was selected to be tested at USCG Station Cape Disappointment, in Ilwaco, WA. The remote imaging system consisted of: 1) a remotely controlled visual camera (closed circuit television (CCTV)) that was controllable both at the tower and remotely from the Station's Communication Center, 2) a low light image intensifier integrated with the visual camera for providing night vision capabilities, and 3) a long-range

thermal imaging camera mounted adjacent to the visual camera to evaluate infrared thermal imaging for both low light and low visibility conditions.

A series of fidelity tests where conducted to assess the remote imaging system's capabilities against that of the Station's current monitoring methods. Viewers using the remote imaging system in the Station's Communication Center were able to estimate wave height as well as an observer physically located in the watch tower. The remote imaging system also increased the ability to monitor the bar beyond daylight hours. The Station now has the ability to monitor the bar 24 hours a day, weather permitting, with the use of the infrared camera. The infrared camera provided some improvement in low visibility conditions (fog, sea spray off breaking waves, etc.), but it was not capable of seeing through all conditions, especially heavy fog. The image intensification capability in the remote imaging system did not provide sufficient performance gains to warrant being recommended as part of a final remote imaging system solution.

An operational performance evaluation of the system's impact on the Station was performed. It was found that the remote imaging system allowed the Station to reduce the amount of time personnel are needed for monitoring from the watch tower. After some hesitancy in trusting the information the remote imaging system provided, confidence with the remote imaging system built and the Station personnel began to use and rely on it. While not completely eliminating the need for tower watch monitoring, the remote imaging system will allow reduced tower manning as weather and conditions permit. The remote imaging system may allow the Station to change its Standard Operating Procedure which requires that first light bar condition monitoring be performed from a Motor Life Boat (MLB). This could result in fuel and workload savings.

The remote imaging system also has allowed the Station's Officer of the Day (OOD) to make better decisions by having more information available or having the same information in a faster timeframe. There is no longer a need to wait for a watchstander to arrive at the tower site before providing the decision maker with this vital information.

A remote imaging system should be installed at all twenty-six Surf Stations to reduce workload. The remote imaging system should consist of a remotely controlled visual camera and long-range infrared camera on a common pan/tilt unit. The remote imaging system should have local control at tower sites to provide the additional imaging capability when manned.

TABLE OF CONTENTS

LIST OF TABLES

1.0 INTRODUCTION

The United States Coast Guard (USCG) Small Boat (Surf) Stations are required to monitor the environmental conditions, monitor vessel traffic, set restrictions when required, and conduct operations over inlet bars within their Area of Responsibility (AOR). The environmental monitoring, although a collateral/secondary duty, is critical to operational success and consists of monitoring weather and the conditions of the inlet (waves, tide, visibility, and other potential restrictive conditions to the safe passage of vessels).

This monitoring is currently done by visual observation. The observation is either done from an appropriate location on shore or by getting underway in one of the Station's small boats. Several Surf Stations have a watch tower located at a convenient location to observe the inlet. These towers are usually not located directly adjacent to the Station. This requires Station personnel to travel to the tower to make observations. Monitoring occurs at a minimum of twice a day (first and last light), as often as every four hours, and more continuously during adverse conditions or times of high vessel activity. Most visual observations are limited primarily to daylight hours.

The conditions of the inlet can change in short periods of time due to weather and/or tides. Weather and tides can induce extremely hazardous, steep or breaking wave conditions at the inlets. The observations of these conditions are used to make critical resource decisions for operational assignments or to restrict vessel traffic. In addition, the Stations record weather and inlet bar condition data, transmit it to the Group, who then report it to the National Weather Service. The Stations record a telephone message on bar conditions which is available to the commercial and recreational marine community. The monitoring and reporting of conditions is a continuous drain on already overburdened Station personnel.

The Stations want to enhance their current monitoring capabilities and reduce, but not eliminate, the need to man the watch tower. Seven Stations in the Thirteenth Coast Guard District stated that there were situations where they felt there was no substitute for having a watchstander in the tower.

This work was performed under a Research & Development Program project in partnership with Command and Control Engineering Center (C2CEN) for the Office of Boat Forces (G-OCS) of U.S. Coast Guard Headquarters. This project is being performed to support the efforts of Project Kimball.

2.0 OBJECTIVE

The objective of this effort was to identify appropriate technologies for Small Boat Surf Stations to aid them in their inlet bar monitoring. The goal was to improve their monitoring performance and reduce the amount of time personnel where needed for monitoring. The goal was to not completely eliminate the need for on-scene monitoring, but provide an alternative for a safer and more efficient method to monitor inlet bars during certain weather and bar conditions.

3.0 TECHNICAL APPROACH

Meetings were held with Station personnel from both coasts to discuss requirements for monitoring inlet bars. A review of available technology was conducted. Finally, a remote imaging solution for inlet bar observations was tested at USCG Station Cape Disappointment. Station Cape Disappointment is located on the north side of the mouth of the Columbia River, and is co-located with the National Motor Life Boat School (NMLBS). This Station was chosen because it provided some of the worst case conditions, both in weather conditions and observation distances. The approach taken was to provide a watchstander in the Station's Communications Center with a means of monitoring the condition of the inlet bar remotely from the Station.

A remotely controlled visual camera system, commonly referred to as closed circuit television (CCTV), was selected to provide the watchstander with a black and white visual picture of the conditions. The black and white video camera was selected due to its superior low light level integration capabilities. Through the use of an integrated pan/tilt unit and telephoto lens, the watchstander or other operator can control both the area and level of detail being viewed.

To increase the viewing time beyond daylight hours and during low visibility conditions, two additional imaging technologies were assessed for their effectiveness. The first was the addition of an image intensifier that rotates into the visual camera's optical path. It provides night vision capabilities by intensifying any available light. The second was a long-range

infrared thermal imaging camera. Either of these technologies could be selected by the operator as conditions warranted.

The real-time video signals from the camera to the Station and control signals from the Station to the camera system where transmitted via video fiber optic modems over cabling that existed at the demonstration site. A local camera control and viewing station was also established at the remote tower site to provide the remote imaging system capabilities (mainly night vision and infrared) to watchstanders assigned to the watch tower. A 24-hour capable video recorder was connected to the remote imaging system for documentation.

To determine the effectiveness of the remote imaging system, two evaluations were performed over a four-month period. One evaluation measured the fidelity of the system's capabilities against the Station's current observation methods. To determine which method had greater fidelity, watch standers observed and documented conditions at known locations using both the new imaging system and the traditional observation methods.

The second evaluation attempted to measure the operational performance effects the remote imaging system had on the Station's operations. The goal was to determine if monitoring information could be obtained in less time than the traditional methods, if trips to the tower by watchstanders or small boat runs to make monitoring observations could be reduced. The number of times per month when the tower was manned through the evaluation period was then compared to previously reported manning times. The evaluation recorded when the remote imaging system alerted the station watchstanders to situations, when it provided information for decision making, and when the Station took action based solely on remote imaging system information. This information was gathered throughout the evaluation period and reviewed for changes associated with familiarity with the remote imaging system . Environmental conditions data (time, precipitation, visibility, NOAA Columbia River Bar meteorological data buoy #46029, and forecasted conditions) were recorded. This information was used to assess any impact weather had on the use of the remote imaging system .

4.0 PERFORMANCE EVALUATIONS

4.1 Fidelity

Eight fidelity tests were conducted. Each test consisted of recording weather conditions (wind, precipitation, and visibility), tide conditions, observer's experience level, and observations on conditions at 15 navigation aids or other definitive objects within the observation area. The test objects were a series of navigation aids located throughout the bar inlet area, including navigational aids upriver from the tower site. The test objects were located from 1 to 4.25 nm from the tower site. Observations were made using the remote imaging system and by traditional methods. Recordings were made if the object was visible or not. If visible, a wave height estimate or other observation was made for that location. The tests were mostly conducted during daylight hours, some were conducted at or just after sunset. The weather during the fidelity tests included clear weather, haze, fog, and rain. Wind speeds ranged from 3 knots up to 27 knots. The average wind speed was 13 knots over all the tests. The visibility reported was generally three nautical miles (nm) or greater.

The weather at the Station throughout the evaluation period can be characterized as unusually good. There were no severe storms, rainfall was approximately half of normal conditions and maximum winds were never higher than 65 knots. Winds have exceeded 100 knots during some winter storms in the same period during other years.

It was determined that test objects in very low visibility conditions could not be seen using traditional/existing methods or with the camera imaging system. The number of times this occurred was not recorded. In general, it was found that observers were able to estimate the same wave heights using the camera system as the exiting methods.

The farthest object from the tower was the Columbia River Entrance #1 buoy (Light List No. 9905) located approximately 4.25 nm from the tower. In five of the eight tests, this object was not visible via either method due to reduced visibility. In two of the eight tests, the object was visible using both methods and the same wave height estimate was recorded. In both of these tests, the weather was listed as good with unlimited visibility. In one test, the buoy was visible using both methods, but not clear enough to estimate a wave height with the remote imaging system. For that observation. the weather reported was wind at three knots, occasional

rain, and unlimited visibility at times. The buoy not being visible enough with the remote imaging system to make a wave height estimate is probably attributed to one of two factors.

First, during the evaluation period a shorter focal length lens (less magnification) than optimum for the distances involved was used due to excessive camera mount movement in high wind conditions. Excess camera movement would have resulted in the operator not being able to keep a desired object in frame. After the evaluation period ended, a method was devised to reduce the camera mount movement and a longer focal length lens was installed. The second factor might have been weather related. The weather was recorded as unlimited at times, although it is unclear from the data sheet whether the visibility was unlimited at the time of the test.

Station personnel report that the image intensification (night vision) of the remote imaging system worked best about one and one-half hours after sunset, and again one hour before sunrise. The image intensification did magnify navigational lights on vessels and buoys during darkness, but was not sufficiently discriminating for identifying bar conditions. The intensified navigational lights would produce an image bloom on the display, which was not useful in identification other than that there was a light there. Wave heights could not be estimated due to the typical overcast conditions at this site during the test period, and it is not surprising that the image intensification had limited benefit. A clear moonlit night would be the ideal condition for using the image intensification part of the system. This area of the Washington and Oregon coast, specifically Astoria, only has 50 days of clear weather on average (during daylight hours) according to National Weather Service data. It seems safe to assume then that the area does not have many more clear moonlit nights. The benefits of the image intensification technology might be greater at other locations, such as the East Coast sites, but not significantly enough to justify its $6K/unit cost of providing this capability.

The infrared (IR) camera provided the biggest performance gain. It was effective at providing images beyond the capabilities of the visual camera, the intensified image, and the traditional observation methods. It provided images in daylight and in complete darkness. It provided better images through haze and thin fog than the visual camera. It was not effective in seeing through heavy fog conditions. The water droplets in the air during foggy conditions attenuate the thermal energy being transmitted off objects, reducing the radiated energy being received by the camera. As the fog gets thicker, there are more water droplets in the viewing

path and the effective range of detection diminishes. At this site in thick fog, the range of the infrared camera was limited to the top of the bluff, generally less than 200 feet, which was slightly above the human vision range in those conditions.

The fidelity tests were not discriminating enough to clearly identify all the times when the IR camera outperformed the visual camera or intensified image. However, discussions with watchstanders and Duty Watch Officers indicate that the IR camera provided more useful images than the other methods used. It was clearly the sensor of choice for most nighttime observations. The IR camera would provide the observer with a thermal profile of a vessel versus the visual camera providing only its light signature. The thermal profile of the vessel aided in the watchstanders' ability to identify the type of vessel. Image intensification of the vessel's image would only brightened the lights on small vessels into an image bloom; however, it was able to provide some identification of large deep draft vessels at closer ranges.

The IR camera also outperformed the visual camera in some daylight observations. In reduced visibility conditions (through light fog, distant viewing in hazy conditions, operations in the area of sea mist coming off breaking waves such as in the training area, or in the glare at sunset) the IR camera was able to provide a more useful image to the watchstander. The visual camera would display the white haze or glare and a faint image of the object, while the IR camera would usually show the object more clearly allowing identification.

The general conclusion that can be drawn from reviewing the data collected and observations made by watchstanders is that the remote imaging system provided nearly equal fidelity in observing inlet bar conditions during daylight hours as a manual watchstander in the tower. The IR camera had superior capabilities during some low visibility and night observations. The timely information provided to the Communications watchstander and the duty watch officer was beneficial to resource allocation decisions.

4.2 Operational Performance

The remote imaging system's impact on operations was evaluated by collecting information on its usage. A questionnaire was filled out by operators of the remote imaging system and decision makers (Duty Water Officers). A remote imaging system usage data sheet, which recorded the number of times the remote imaging system was used in Station operations

or decision making, was filled out monthly. The questionnaire asked questions about the use of the remote imaging system during the watchstander's watch. The questions were designed to be answered by the tower watchstander, communications watchstander, and the Officer of the Day.

The remote imaging system usage data sheet recorded information to determine the impact of the system's usage on the Station's operations. The following information was recorded on the data sheet: the number of times per month that the tower was manned for monitoring, the number of times per month the remote imaging system initiated a tower watchstander be sent to the tower, and the number of times per month that a MLB was required to get underway to monitor the bar, and when the system initiated an underway monitoring check. The number of times per month the system was used in Law Enforcement (LE), Search and Rescue (SAR), and Marine Environmental Protection (MEP) cases were also recorded on the data sheet. This information is presented in Table 1.

Table 1. Remote Imaging System Usage Impact

Evaluation Factors	Quantities per Month					Totals
	Sept*	Oct	Nov	Dec	Jan*	
Bar Condition Monitoring						
Watch sent to Tower	40	124	120	124	96	504
System identified need to send watch to tower	3	15	18	19	19	74
MLB was used to check bar	10	31	30	30	24	125
System identified need to send MLB to check bar	0	0	0	0	0	0
Law Enforcement (LE)						
System used in LE case	0	3	0	1	0	4
Marine Environmental Protection (MEP)						
System used in MEP case	0	3	0	1	0	4
Search & Rescue (SAR)						
System used in SAR case	3	4	2	9	4	22

* Evaluation Period 22 Sep 2000 thru 24 Jan 2001

The remote imaging system usage data in Table 1 shows that the Station continued its standard procedure of using an MLB to check the bar each morning (first light), with the

exception of one day. In December, to expedite training being conducted at the Station that day, the OOD chose to forgo the MLB first light bar check and relied on the remote imaging system. Conditions listed for that day were favorable for remote monitoring, unlimited visibility with light winds and 4-8 foot swells. Reducing workload at the Station to allow tasks such as training to be performed was the goal of this effort.

The Station's Commanding Officer indicated that the Station's Standard Operating Procedure (SOP) would not be changed until changes had been discussed and concurred on by both the Group and District offices. He did indicate that now that his staff had become familiar with the remote imaging system and are able to reliably estimate wave heights with the remote imaging system, he was more comfortable in modifying the Station's SOP to incorporate the system's capabilities. This is especially likely in light of the proposed fuel usage reductions for the Station.

Information from the remote imaging system was also used by the OOD to aid in determining if a Coxswain or Surfman was needed to complete the mission. They also state that the remote imaging system will have its highest utility during the July-September recreational boating salmon season. During that time they can have upwards of 1000 boats located between "Buoy 10" and the Astoria-Megler bridge.

Table 1 also reflects that the remote imaging system was used in 22 SAR cases, 4 LE cases, and 4 MEP cases. The Station reported that the remote imaging system had become a useful tool after the fascination of the "new toy" had worn off. They reported that the OOD would use it to eliminate sending a watchstander to the tower, if using the system's images they could ascertain that the conditions were still calm. They would also use it to notify them when conditions changed, warranting sending a watchstander to the tower. Notification of changes in conditions using the remote imaging system occurred on average 17 times per month.

5.0 CONCLUSIONS

The remote imaging system was shown to be a valuable aid at surf stations. The remote camera provided the Station with improved inlet bar monitoring, in addition to reducing the amount of time personnel were needed for monitoring conditions from the watch tower. After some hesitancy in trusting the remote imaging system, familiarity with the remote imaging system grew and the Station personnel began to use and rely on it. While not completely

eliminating the need for tower watch monitoring, the use of the remote camera system will allow tower manning to be reduced as weather and conditions permit.

The remote imaging system also increased the ability to monitor the bar beyond daylight hours. The Station now has the ability to monitor the bar 24 hours a day, weather permitting, by use of the forward looking infrared camera. The infrared camera has provided improved visibility in reduced visibility conditions (fog, sea spray off breaking waves, etc.), but it is not effective in conditions such as heavy fog.

The remote system also allowed the Station's OOD to make more informed decisions by having more information available and/or the same information in a faster timeframe. There was no longer the need to wait until a watchstander arrived at the tower site to start providing important decision making information.

6.0 RECOMMENDED REMOTE IMAGING SYSTEM

Based on the testing of the remote imaging system at USCG Station Cape Disappointment, recommendations on minimum system requirements are provided below. Due to the variety of conditions at the different Stations, several important parameters are not specifically defined and will have to be addressed on a case-by-case basis.

The full motion real-time remote imaging system shall consist of:

- CCTV digital camera (black & white or color)
- Remotely controlled zoom lens (focal length determined by site requirements)
- Camera housings with deicing heaters, defogging fans, and remotely controlled wiper for the camera housing's lens.
- Forward Looking Infrared Camera (FLIR) w/cooled detector operating in the 3-5 micron spectrum. (Lens requirements to be determined by observation distances at the individual sites.)
- Operator selection of camera being viewed both locally at the tower site and remotely at the Station
- Local and remote shut down of the FLIR camera to preserve its operational life
- Remotely controlled pan/tilt unit rated for high wind loads (100-125 mph)

- Full two-way control both locally in tower and remotely in Station's Communications Center

There are tradeoffs between selecting a black and white visual or a color camera. Black and white digital cameras have better low light abilities. They can integrate the light available over several frames to increase the image brightness, and thereby mitigate the need to add any light intensification equipment. Color cameras are able to discriminate an object's color (a red hull, for example), but do not have the same low light capabilities as black and white visual cameras.

Based on the fidelity tests, it was determined that providing image intensification to enhance night vision capability is not warranted. The intensification of existing light was only beneficial for a short period after sunset and before sunrise. During other hours of nighttime use, it would only magnify existing lights (vessel and navigational lights) to the point of blooming. The bloomed image was not useful in condition monitoring or vessel identification. The short period of gain in performance does not warrant the $6K per unit cost and associated maintenance of this optical/mechanical device.

Costs to install a remote imaging system are estimated to be between $70K to $95K per Station. That cost is broken down to between $20K to $25K to install a visual camera system that is remotely operated. Site conditions, distances involved, and signal transmission paths are the primary variables involved. A long-range infrared camera is estimated to be between $50K to $70K. Distances involved and economies of multiple unit purchases are the primary variables in this cost. A single unit purchase with optics for a two to four mile range is estimated to be approximately $70K.

There will also be maintenance and replacement costs for the equipment. There are many variables involved in maintaining a system; for example, whether the system is maintained by Coast Guard personnel (ESU's) or support is contracted on a yearly basis. It is estimated that engineering logistics support through C2CEN would cost approximately $40K to support all twenty six Surf Stations.

The type of IR camera recommended for this application typically has a mean time between failures rate of 4000 hours. This number is for continuous use in laboratory ambient conditions. Hotter or cooler conditions at a site will affect rate. The rate is driven by the

detector's cooling system. The camera's detector is cooled to 70 ^{o}K (Kelvin) by a sterling cooler operating on helium. The 4000 hour rate is the time between recharges of the cooling system. Camera refurbishment (cooler recharging and alignment checks) costs approximately $6K every eighteen to twenty-four months based on typical part-time usage.

The visual camera and lens has an estimated life of 2-3 years. The pan tilt unit has an estimated life of 4-5 years. The communications equipment has an estimated life of 3-4 years. Using an industry standard cost projection of 10% of purchase cost, maintenance and replacement of the remote imaging system (not including the IR Camera) is estimated to be $2.5K per unit per year or $65K per year for the twenty six stations.

In summary the estimated costs for the proposed remote imaging system are $70K to $95K per Station to install and $5.5K to $6.5K per year in maintenance and replacement costs.

Table 2. Estimated System Costs

	Per Station Cost	26 Station Cost
Hardware/Installation	$70-95K	$1,820K-2,470K
Maintenance/year	$5.5K-6.5K	$143K-169K